



**UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10**

1200 Sixth Avenue, Suite 900
Seattle, Washington 98101-3140

July 20, 2017

Reply to: OERA-140

TECHNICAL MEMORANDUM

SUBJECT: Groundwater Sampling and Hydraulic Monitoring at Lakewood/ Ponders Corner Superfund Site, April – November 2016

FROM: Bernie Zavala, Hydrogeologist *B. Zavala*
Office of Environment Review and Assessment

TO: Tracy Chellis, Remedial Project Manager
Office of Environmental Cleanup

The EPA Region 10 Office of Environmental Cleanup tasked the Office of Environmental Review and Assessment to conduct groundwater sampling and hydraulic monitoring at the Lakewood/Ponders Corner Superfund Site. The monitoring was completed to assess the current protectiveness of the on-going remedy at the site to support the sixth Five Year Review which will be completed by September 2017. This assessment included the installation of two new monitoring wells, the continuous collection of hourly groundwater elevation data from six monitoring wells within the site vicinity and the collection of groundwater quality data, volatile organic compounds (VOCs) for the contaminant of concern (COC) Tetrachlorethene, (PCE) and its daughter products Trichlorethene (TCE), Cis-1,2-Dichlorethene (Cis-1,2 DCE) and Vinyl Chloride (VC). The installation of the monitoring wells was conducted and completed by EPA's contractor (ENE) in January 2016 (ENE, 2016). The collection of the groundwater quality data and hydraulic data took place over the time period from April to November 2016 (EPA, 2016).

Background

The Site is located in the city of Lakewood in Pierce County, Washington, Figure 1.0. In 1981, EPA sampled the Lakewood Water District drinking water supply wells H1 and H2. The tests result indicated that wells H1 and H2 were contaminated with volatile organic compounds (VOC), i.e., PCE, TCE and cis-1,2 DCE. The source of contamination was identified as Plaza Cleaners, a dry cleaning and laundry facility.

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The Lakewood/Ponders Corner Superfund Site was listed on the National Priorities List (NPL) on December 30, 1982. A Record of Decision (ROD) was signed on June 1, 1984 to include the installation of the air strippers to treat contaminated groundwater. A remedial investigation and feasibility studies were completed during August 1984 through July 1985. Selected remedies to address soil contamination at Plaza Cleaners included the excavation of contaminated soils, removal of contaminated sludge and off-site disposal. A Record of Decision (ROD) was signed on September 30, 1985 and amended in November 14, 1986 to include the installation of a soil vapor extraction system (SVES) for treating a small portion of contaminated soil in the vadose zone. An Explanation of Significant Difference (ESD) was signed in 1992 to excavate additional soil and sludge in the septic field. The soil remediation was completed in 1993 and EPA announced in the Federal Register the partial deletion of the Lakewood site "Soil Unit" from the NPL, effective November 27, 1996.

The selected remedy for groundwater was a well head treatment system. By November 1984, two air strippers were constructed at Lakewood Water District production wells H1 and H2 and began operating to treat the contaminated groundwater. The treated groundwater meets Safe Drinking Water Act Maximum Contaminant Levels standards (after air stripping). The groundwater treatment system is still in operation, since the groundwater cleanup levels have not been achieved throughout the site.

EPA conducted five-year reviews in 1992, 1997 and 2007. Washington Department of Ecology (Ecology) conducted a five-year review in 2002. The fifth five-year review was conducted by the U.S. Army Corps of Engineers (USACE) for EPA in September 2012.

The original conceptual model for the site is presented in Figure 2. This conceptual site model shows a downward vertical gradient from Zone B, till unit to Zone A, the outwash sands. This conceptual model does not appear to be consistently correct during the entire year. Later in this report data are presented which documents that the vertical gradient changes to upwards during parts of the year.

The production wells and air stripper operations and maintenance are conducted by the Lakewood Water District. Groundwater monitoring is performed by Ecology. The remedy is functioning to the extent that extracted groundwater is suitably treated for public consumption. The pump and treat system does appear to capture the contaminated groundwater in the advanced outwash unit when both H1 and H2 are pumping. Residual PCE contamination has been detected in the hydro-geologic till unit (B-zone) with detection above the MCL for PCE, and the groundwater concentration have been decreasing with time. The continued downward vertical migration gradient of contaminants from the low permeability soils (B-zone) is the likely cause for ongoing impacts to groundwater in the lower (A-zone) or the advance outwash sand, Figure 2.0, (EPA, July 1985). This is evidenced by concentration of PCE in MW-16A when groundwater is moving toward H1 and H2. This is consistent with the conceptual site model for the Site. It is acknowledged that continued leaching of PCE from the till unit will likely require the continued operation of the air strippers on the public water supply

wells. The pumping of production wells H1 and H2 does produce a capture zone which contains the impacted groundwater in the advance outwash sand when pumping but it does not directly impact the above till unit. MW-20B which is screened in the till unit was known to have a downward vertical hydraulic gradient. The vertical water quality data downgradient of MW-20B does show PCE concentrations in MW-16A which continues to flow towards the pumping center of H1 and H2. This is evidence that pumping of H1 and H2 does have a positive impact on controlling the plume coming from the till unit to the advance outwash towards the pumping center of H1 and H2.

Project Objective and Task Descriptions

The overall objective of this field study is to make an assessment on the current protectiveness of the remedy when H1 and H2 are operating in a non-continuous manner along with the new groundwater quality data on PCE concentration from the installation of the two new monitoring wells.

The Lakewood Water District in recent years has been operating the well field or the pumping of H1 and H2 in a non-continuous manner and it was estimated that the wells may be shut off approximately 40% of the time (Lakewood Water District, September, 2014). Also, Ecology had decommissioned four downgradient monitoring wells, MW-21, 27, 28 and 41. EPA felt it was important to look closer into the discontinuous pumping of the wellfield and the loss of the groundwater monitoring locations to see how these changes may affect the protectiveness of the current remedy.

Figure 3.0 taken from the Trip Report by Ecology and Environment Inc. when they recently (January 2016) installed two monitoring wells for EPA shows the present locations of the monitoring wells and the production wells, H1 and H2. The four monitoring wells that were decommissioned by Ecology were MW-41, MW-27, MW-28 and MW-21. EPA was able to re-install two new monitoring wells and selected the locations for these new monitoring wells near the old locations of MW-28 which was renamed MW-28R and the other location MW-41 and renamed it MW-41R. These two placement monitoring well locations were chosen based on the natural groundwater flow or the groundwater flow direction when the productions wells were not in operation. This information regarding the natural groundwater flow direction was found in a journal, *Ground Water Monitoring Review*, Fall 1983. This journal article listed the flow direction from H1 and H2 trending in a north-northwest direction or approximately 320 degrees north (Keely and Wolf, 1983). MW-28R and MW-41R appear to be horizontally down gradient of the highest PCE monitoring wells MW-20B and 16A when pumping is not taking place at H1 and H2.

The objective of the groundwater sampling and the water level measurements is to determine both water quality or concentrations of PCE and its daughter products and the groundwater flow direction both horizontally and vertically. These data should provide insights on how these changes might have affected the protectiveness of the current remedy. The ten monitoring well that were sampled can be found in Table 1.0. Six of

those monitoring wells had transducers that recorded the groundwater elevations on an hourly basis during the duration of this study.

Hydraulic Monitoring Data

The transducer data or the groundwater elevation data that was collected from March to December 2016 was plotted up, see Figures 4.0 through 8.0, MW-31, 28AR, 20A, 20B, 16A and 16B had transducers installed and collected data on an hourly basis. These figures provide general information on the seasonal effect on the potentiometric surface for all six monitoring wells. The thickness of the blue line is a factor of the compressed graphic presentation of the wells fluctuation during the pumping cycles in wells H1 and H2. In general, the highest groundwater elevation occurred during the month of March and the lowest elevation in late September with the groundwater elevation rising again due to recharge through precipitation or rainfall.

Figure 4.0, MW-31 the screen interval was monitoring the advance outwash sands at a depth of 187.11 to 202.11-feet above mean sea level (AMSL). Figure 5.0, MW-28AR which was one of the replacement wells has a screen interval monitoring the advance outwash sand at a depth ranging between 182.17 to 202.17 feet-AMSL. Figure 6.0, MW-20A has the screen interval monitoring the advance outwash sand at a depth of 178.26 ranging between 188.26-feet AMSL and MW-20B has a screen interval monitoring the till unit at a depth of 228.03 ranging between 238.03-feet AMSL. Figure 6.0 displays a vertical upward hydraulic gradient or groundwater flowing from the lower outwash sand to the till unit throughout this monitoring period. Figure 7.0, MW-16A and B are both screen within the outwash sands. MW-16A the deeper of the two monitoring wells has a screen interval at a depth of 174.06 ranging between 179.06 feet-AMSL while MW-16B has a screen interval at 206.8 to 208.8 feet-AMSL (EPA, 1983). Figure 7.0, does displays a typical hydrograph when monitoring the same aquifer unit being the outwash sand or the gold line (MW-16B) matches and tracks the upper portions of blue line or MW-16A. The three vertical gold lines show the water levels after MW-16B was purged and sampled when the transducer was placed back into the monitoring well it took approximately 7-days for this monitoring well to recover to a similar head or groundwater elevation similar to MW-16A. Even though these two monitoring wells were hydraulically connected MW-16B has a shorter screen interval with the local lithology having a lower permeability.

The other interesting item to note on Figure 4.0, 5.0, 6.0 and 7.0 for the monitoring wells in the outwash sand the thick blue line becomes a thinner line starting on June 27 to July 15th. This thinner line displays the water elevations when the Production wells were pumping in a continuous manner during this time period. Figure 8, shows this hydrograph for a shorter period of time and you can visually see the change in groundwater elevations. Figure 8.1 is another example that shows the change in groundwater elevations for shorter period of time when the productions wells were both on and off. The data shows an approximate 2-feet head difference on June 27 when the production wells (H1 and H2) were operating in a continuous manner. The top blue line is most likely

the groundwater elevation when the production wells are shut-off. The lower blue line are the groundwater elevations when the production wells are pumping.

Groundwater Flow Direction and Capture Zone

Five groundwater quality sampling events took place during this study on April 27, June 8, July 21, September 13 and November 17, 2016. During these sampling events groundwater elevations were collected by two methods (1) tagging the depth to water from the top of the monitoring well casing using an electric water level sounder and (2) the collection on an hourly basis of water level using a transducer in six different monitoring wells, which were previously mentioned. The groundwater elevations in each of the monitoring wells are influenced by the pumping of H1 and H2 at the Lakewood well field but information on pumping rates and pumping durations weren't available and that information was not included in this study.

Figure 9.0 through 13.0 shows the groundwater flow direction for each sampling event by displaying groundwater contours and flow vectors for the outwash sands unit or zone A. The April and June event shows a general flow direction to the northwest where Gravelly Lake is located and which may also be the local sink for this groundwater. A red ellipse appears around the pumping wells H1 and H2 which is referred to as the *zone of contribution* (ZOC). The groundwater in this area (ZOC) is moving towards the pumping wells; this is also referred to as the capture zone for the pumping wells. Appendix A has the calculations that was performed to determine this ellipse by calculating the point of stagnation or divide where the groundwater is flowing to the pumping well and the width of the ellipse that is produced by the pumping wells, (EPA,2008). Since H1 and H2 are not pumping in a continuous manner hydraulic capture is not being maintained at all times but the flow vectors around plaza cleaners appears to be flowing towards H1 and H2 in all five sampling events. The July sampling events shows the greatest impact of the pumping from H1 and H2 via the flow vectors. It should be noted that figure 8.0 displays continuous pumping approximately on June 27 to July 15, 2016. Also, Figure 20.0 displays a capture zone for H1 at a pumping rate of 1,175 gallons per minute.

Groundwater Quality Data

Five groundwater quality sampling events took place during this study on April 27, June 8, July 21, September 13 and November 17, 2016. Figure 14.0 shows the groundwater sampling collection events on the hydrograph for MW-31. This hydrograph also provides information on the groundwater elevations for each of the water quality sampling events. Figure 15 through 19 shows the concentrations of Tetrachlorethene (PCE) in groundwater for each event. These figure also includes the area of the zone of contribution (ZOC) or the area that would be impacted if the production wells H1 and H2 were pumping in a continuous manner. There were only three monitoring wells that had detections above the MCL of 5 µg/L. They were MW-20B, located within the till unit and 16B and 16A located in the upper portion and lower portion of the Outwash Sands unit. These three monitoring wells were within the zone of contribution or the capture zone area. The other

seven monitoring wells water quality were not detected at the reporting limit of 1 µg/L or just above it. MW-32 in June and November had PCE detection of 1.1 µg/L. MW-20A which is screened within the outwash sands similar to MW-16A and located within the ZOC was non-detected for PCE in all five events. The up-gradient monitoring wells MW-19A and B were also non-detected for PCE in the first three events and these wells weren't sampled during the September and November events. Table 2.0 through 6.0 shows the analytical results for all the monitoring wells sampled for the volatile organic compounds, PCE and its daughter products. Trichlorethene (TCE) and Cis-1,2-Dichlorethene were also detected at low concentrations at the three monitoring well locations of MW-16A & B and MW-20B. No Vinyl Chloride was detected in any of these five events for any monitoring well.

Duplicate samples were collected as part of quality assurance for all five events for sample locations MW-16A, 19A, 20B. The sample results were within acceptable quality assurance criteria.

Discussion and Conclusions

The overall objective of this field study was to make an assessment on the current protectiveness of the remedy when H1 and H2 were pumping in a non-continuous manner, in combination with the new groundwater quality data on PCE concentration from two new monitoring wells. The focus was on the water quality data collected during the period from April to November 2016 and the hydraulic data that was collected by transducers on an hourly basis for the groundwater elevations during this same time period.

The water quality results didn't differ from previous results where MW-16A and MW-20B were still above the MCL similar to data that was collected by Ecology in October 2015 (Ecology, 2015) and the groundwater flow direction under "natural" flow direction or flowing to the north-northwest to Gravelly Lake, all five of those monitoring wells were below the MCL with only one monitoring well MW-32 with a detection of 1.1 µg/L in June and November. EPA in 2016 also sampled MW-16B which is screened at the upper portion of the outwash sands unit. PCE was detected during all the five sampling events but only twice exceeded the MCL. It should be noted that the B-Zone is the shallow depth zone and it is considered the till geologic unit with a low hydraulic conductivity. It is for the most part considered an aquitard but within the vicinity of MW-20B it should be considered an aquiclude, where it is capable of amount of water for production, storing and releasing water but does not transmit it at rates sufficient to furnish an appreciable

The previous conceptual site model Figure 2.0 shows a downward vertical gradient from Zone B, till unit to Zone A, the outwash sands. This conceptual model does not appear to be correct in this case during the time period from April to November in 2016 (Figure 2.1) where the vertical gradient is upward, see Figure 6.0. The data collection stopped in late December and condition could be changing to where the vertical gradient could reverse to a downward vertical gradient when there is a higher groundwater table and

greater amount of recharge or rainfall is taking place. On average, the months of November through March receive almost three quarters of the annual rainfall. When the vertical gradient is upward it minimize the flux from the till to the aquifer or the outwash sands, or even keep the PCE from entering the aquifer thus providing a line of evidence for protectiveness during this period of time.

The water quality data changes appear to be seasonal during this study period and also from past groundwater sampling events over many years. The highest concentration of PCE were detected in MW-20B when the lowest groundwater elevation occurred in September and when PCE was at the highest concentration of 410 µg/L. Again, this is when the upward vertical gradients are the highest. When the vertical gradients reverse during high recharge or during periods of precipitation we find the lowest PCE concentration 74 µg/L in MW-20B. Also during the Spring MW-16A has the highest concentration of PCE 63 µg/L.

As an observation from Figures 9.0 to 13.0 or the groundwater elevations the contour lines and vectors point to a groundwater flow direction due west of MW-16A where the PCE concentrations are above the MCL and a boundary monitoring wells or a downgradient monitoring well currently doesn't exist in the outwash sands. It is recommended that an additional monitoring be installed at the same depth of MW-16A (105 to 115-feet BGS). See Figure 20.0 for this location which is located at the south east intersection of Pacific Hwy SW and New York Ave SW. Once this monitoring well is installed and sampled it will fill the current data gap. This new monitoring well will provide an additional line of evidence on whether or not the current remedy is protective.

Based on the above discussion and the data collection during 2016 the current operation of the remedy appears to be **protective** based on the following:

- Groundwater quality north and west of MW-16A is below the MCL for PCE in the outwash sands aquifer and should remain the same as long as Production Wells H1 and H2 continue to pump.
- An upward vertical gradient exists for the months of May through November when the highest concentration of PCE occur in monitoring well (MW-20B).
- The PCE found near MW-20B in the till unit is most likely partitioned on low permeable silty and clay and it is slowly desorbing when a downward vertical gradient exist. This till unit at this location is an aquiclude capable of storing water but transmission of water and contamination may be very slow.
- Based on the water quality concentrations (PCE), the hydraulic gradients and groundwater flow direction it can be concluded that the current remedy is protective.

Recommendations

The pumping of the Production Wells H1 and H2 and the treatment of groundwater by air stripping must continue. The groundwater quality and hydraulic monitoring must continue at the frequency that was recommended by Ecology in the October 2015, Data

Summary Report, (Ecology, 2015). The purpose of the monitoring is to continue to verify that the groundwater concentrations are not changing or significantly increasing from what has been observed in the record. The following are the monitoring wells that must be sampled starting in April 2018. It is also recommended that additional monitoring well be installed by April 2018, see Figure 20.0 for the location.

Monitoring Well locations (Groundwater quality) ¹	Laboratory Analysis	Frequency
MW-20B, MW-16A, MW-32, MW-31, <i>add the new MW- west of MW-16A</i>	Targeted VOCs ²	18-months starting April, 2018
MW-33, MW-19A, MW-28R	Targeted VOCs	36-months
MW-41R	Targeted VOCs	5-years

1- Continue hydraulic monitoring (Groundwater elevation) for MW-20A& B, MW-16A&B, MW-28R, MW-31, MW-32, MW-41R, MW-19A&B, MW-33 and the new monitoring well – Frequency every groundwater quality monitoring event.

2- Targeted VOCs are: PCE, TCE, 1,2-DCE and VC.

Figures

Figure 1.0 Location of Ponders Corner within the city of Lakewood, Washington

Figure 2.0 Groundwater flow Conceptual Site Model (CSM) when H1 & H2 are pumping (1985)

Figure 2.1 Groundwater Flow CSM when H1 and H2 are pumping during the months of April through November 2016.

Figure 3.0 Ponders Corner/Lakewood – Locations of the Monitoring Wells and Production Wells

Figure 4.0 MW-31 Groundwater elevations March 15 through December 20, 2016

Figure 5.0 MW-28AR Groundwater elevation March 8 through December 201, 2016

Figure 6.0 MW-20A and 20B Groundwater elevation April 28 through December 20, 2016

Figure 7.0 MW-16A and 16B Groundwater elevations March 8 through December 20, 2016

Figure 8.0 MW-20A and 20B Groundwater elevations June 25 through July 16, 2016

Figure 8.1 MW-16A Groundwater elevation June 9 through July 21, 2016

Figure 9.0 Groundwater Elevations April 27th, 2016

Figure 10.0 Groundwater Elevations June 9th, 2016

Figure 11.0 Groundwater Elevations July 20th, 2016

Figure 12.0, Groundwater Elevations September 13th, 2016

Figure 13.0, Groundwater Elevations November 18th, 2016

Figure 14.0 Groundwater Quality Sampling Collection Dates on the MW-31 Hydrograph (Groundwater elevation vs time)

Figure 15.0 Tetrachlorethene (PCE) Groundwater Concentration - µg/L April 27th, 2016

Figure 16.0 Tetrachlorethene (PCE) Groundwater Concentration - $\mu\text{g/L}$ June 9th, 2016

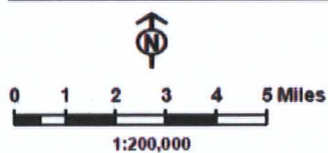
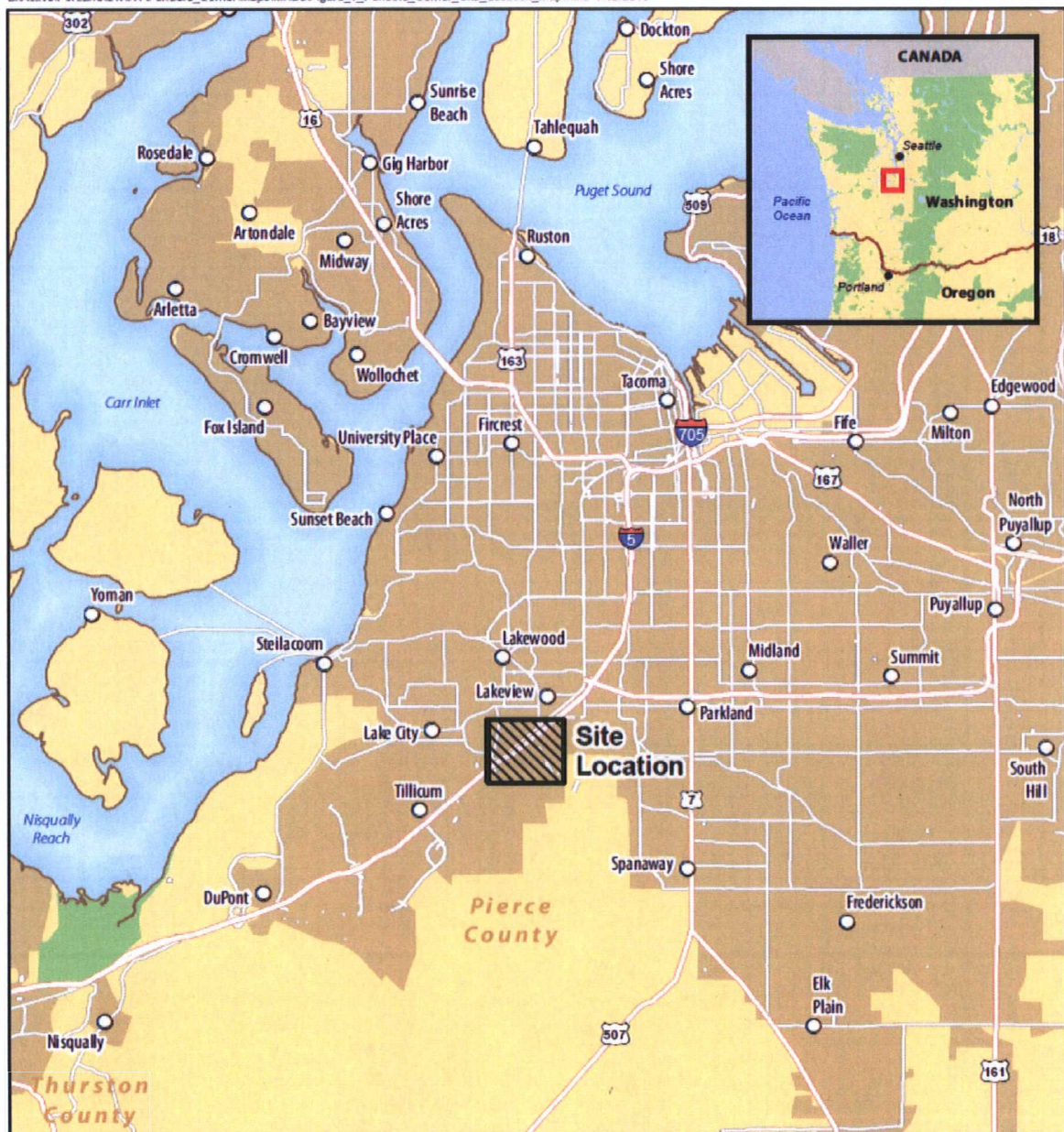
Figure 17.0 Tetrachlorethene (PCE) Groundwater Concentration - $\mu\text{g/L}$ July 20th, 2016

Figure 18.0 Tetrachlorethene (PCE) Groundwater Concentration - $\mu\text{g/L}$ September 13th, 2016

Figure 19.0 Tetrachlorethene (PCE) Groundwater Concentration - $\mu\text{g/L}$ April 27th, 2016

Figure 20.0 Location for the installation of a new monitoring well.

Figure 1.0 Location of Ponders Corner within the city of Lakewood, Washington



Source: Esri, 2012.

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Figure 1
Site Location Map
Lakewood/Ponder's Corner
Well Installation
 Pierce Co., Washington

Figure 2.0 Groundwater flow Conceptual Site Model (CSM) when H1 and H2 are pumping (1985), also a down-ward vertical gradient in MW-20B to MW-20A during the months of December 2015 to March 2016.

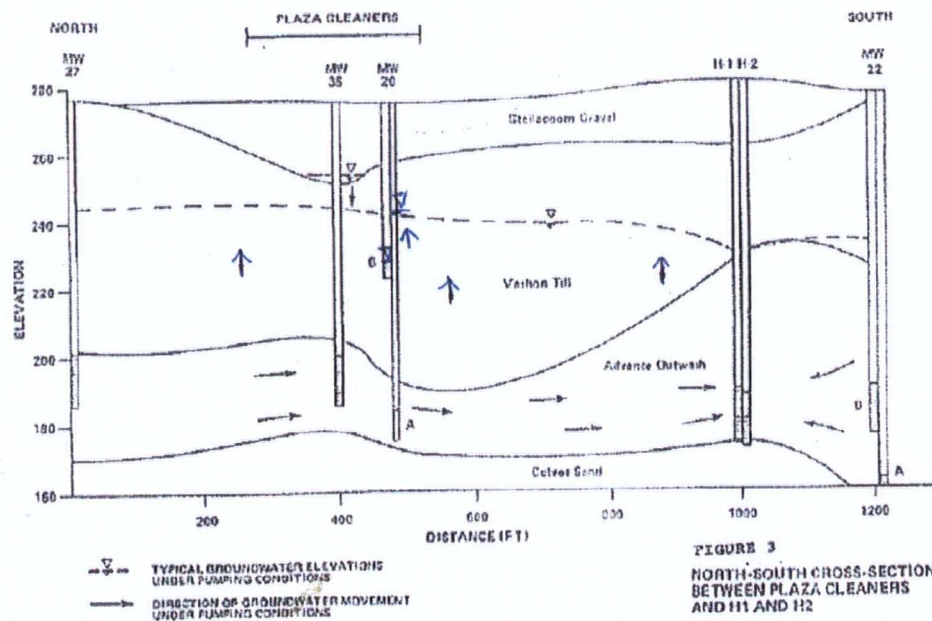
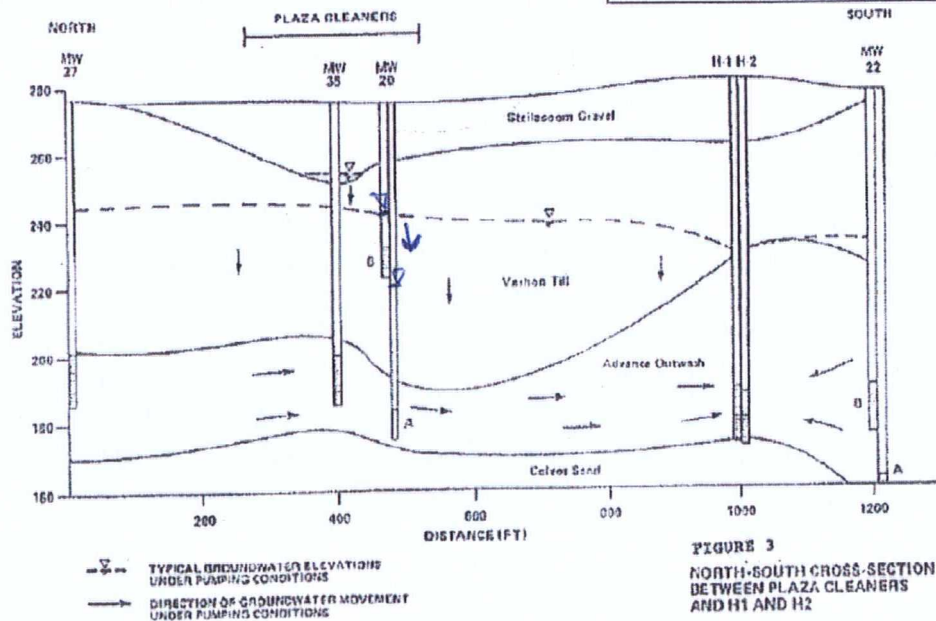


Figure 2.1 Groundwater Flow CSM when H1 and H2 are pumping during the months of April through November 2016, up-ward vertical gradient from MW-20A to MW-20B.

Figure 3.0 Ponders Corner/Lakewood – Locations of the Monitoring Wells and Production Wells



0 500 1,000 Feet
1:8,310

Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNR/Satellite DS, USDA, USGS, AeroGRID, IGN, ICR, and the GIS User
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Well Type
 Municipal
 Active
 Decommissioned
 Unknown

Figure 2
New and Existing
Monitoring Wells
Lakewood/Ponder's Corner
Well Installation
Pierce Co., Washington

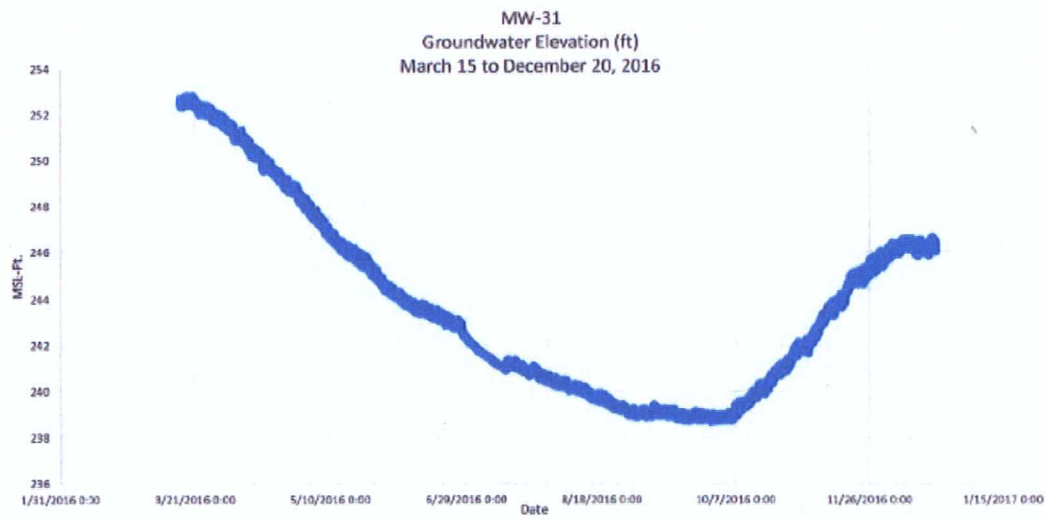
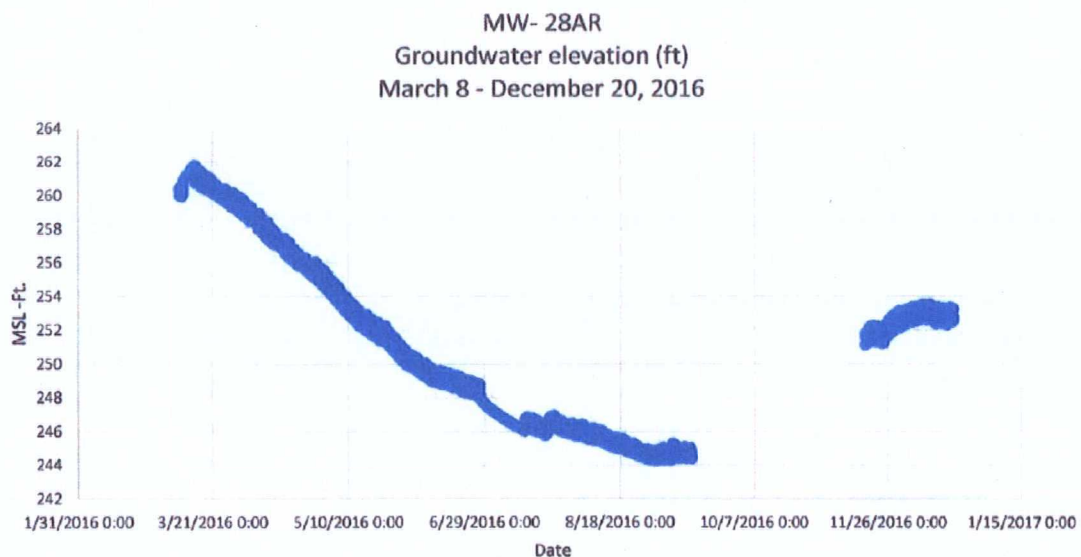
Figure 4.0 MW-31 Groundwater elevations March 15 through December 20, 2016**Figure 5.0 MW-28AR Groundwater elevation March 8 through December 201, 2016**

Figure 6.0 MW-20A and 20B Groundwater elevation April 28 through December 20, 2016

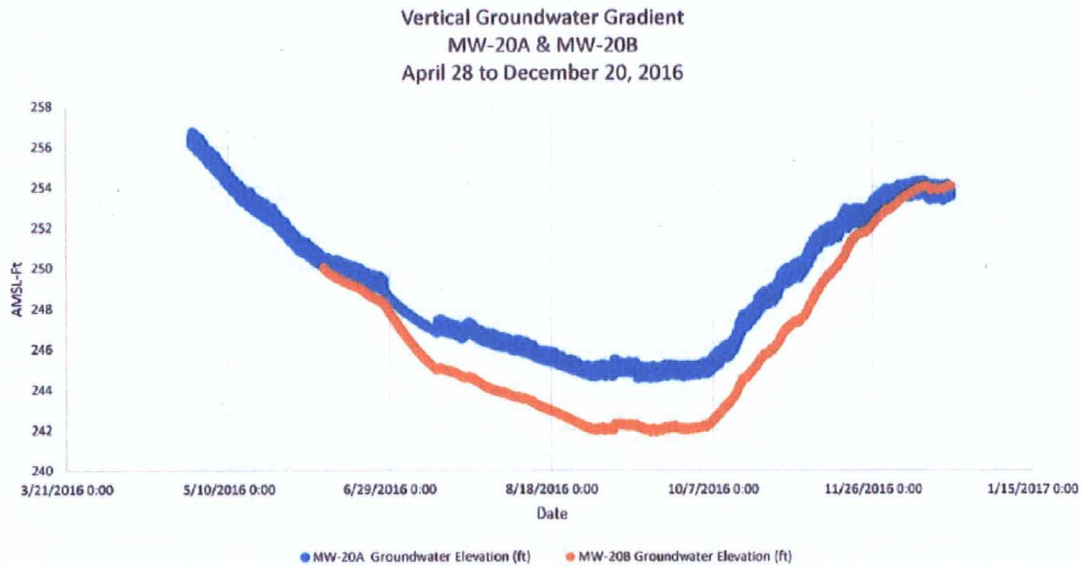


Figure 7.0 MW-16A and 16B Groundwater elevations March 8 through December 20, 2016

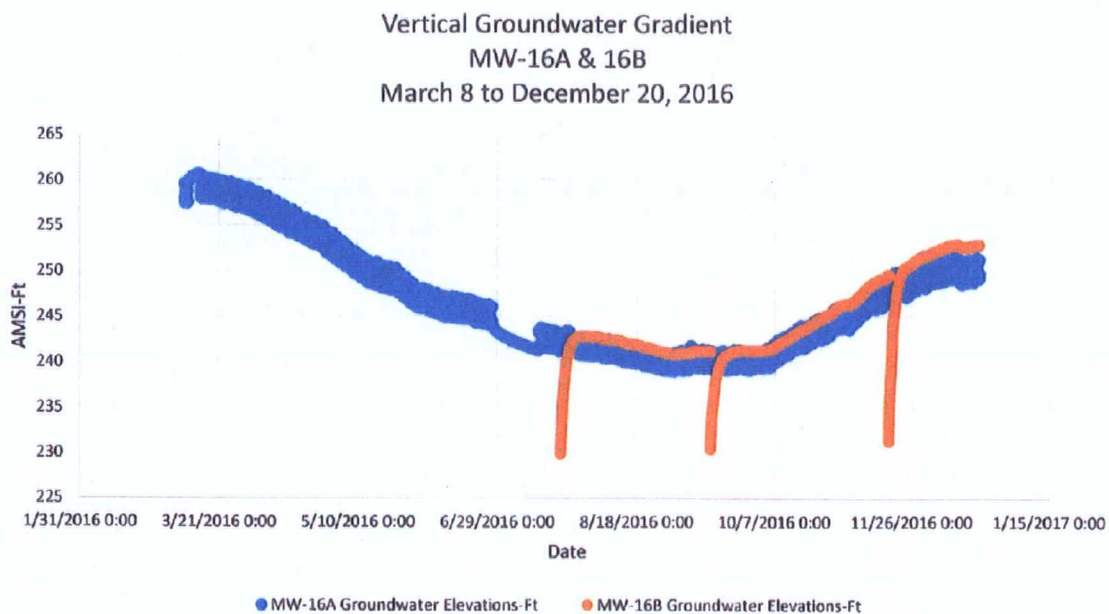


Figure 8.0 MW-20A and 20B Groundwater elevations June 25 through July 16, 2016

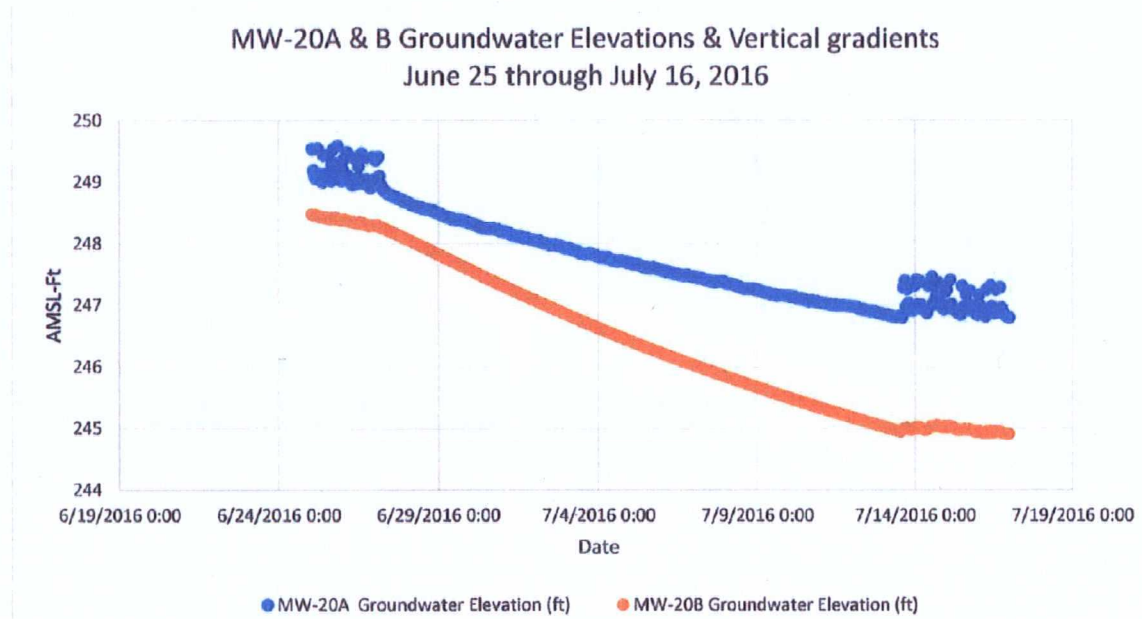


Figure 8.1 MW-16A Groundwater elevation June 9 through July 21, 2016

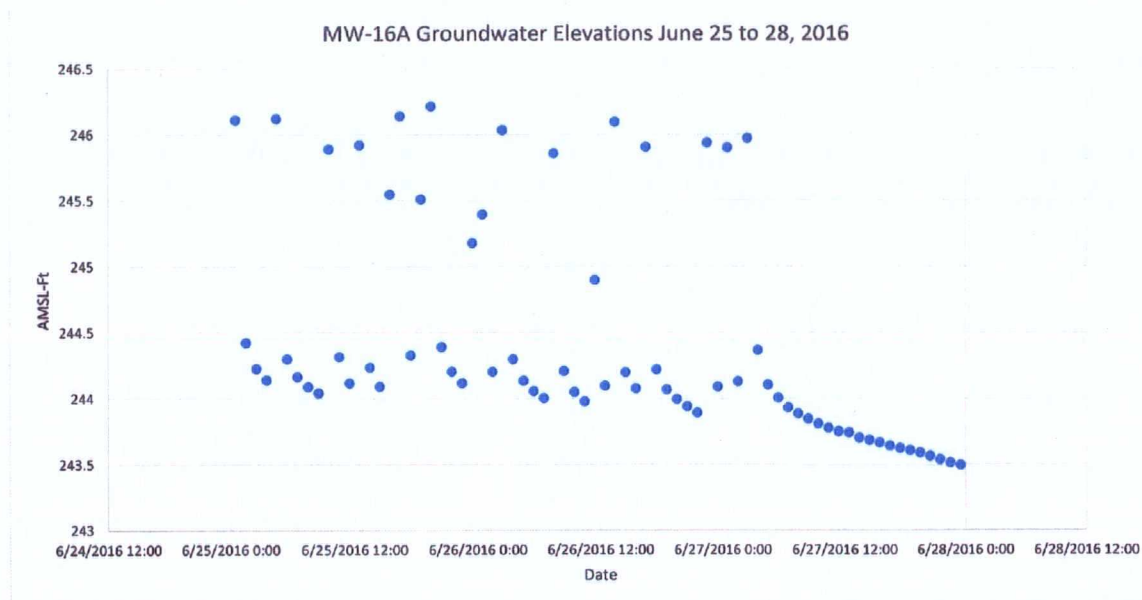


Figure 9.0

Groundwater Elevations April 27th, 2016

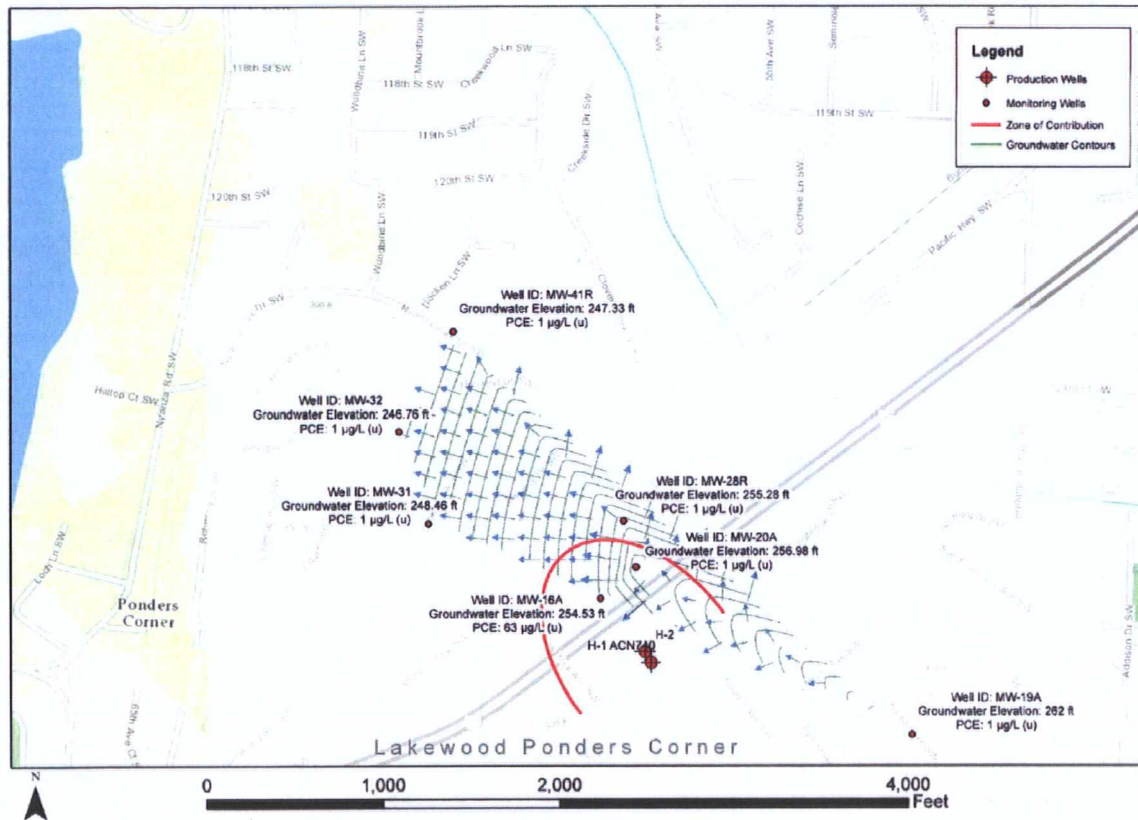


Figure 10.0

Groundwater Elevations June 9th, 2016

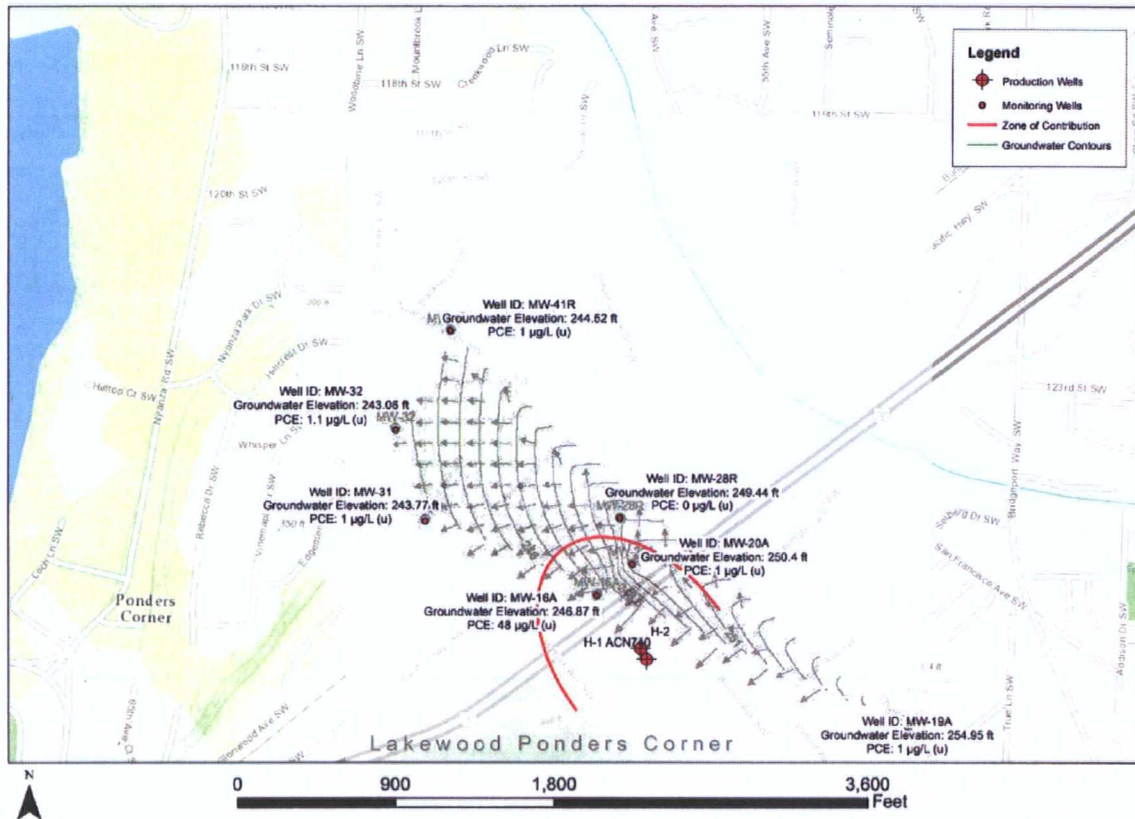


Figure 11.0

Groundwater Elevations July 20th, 2016

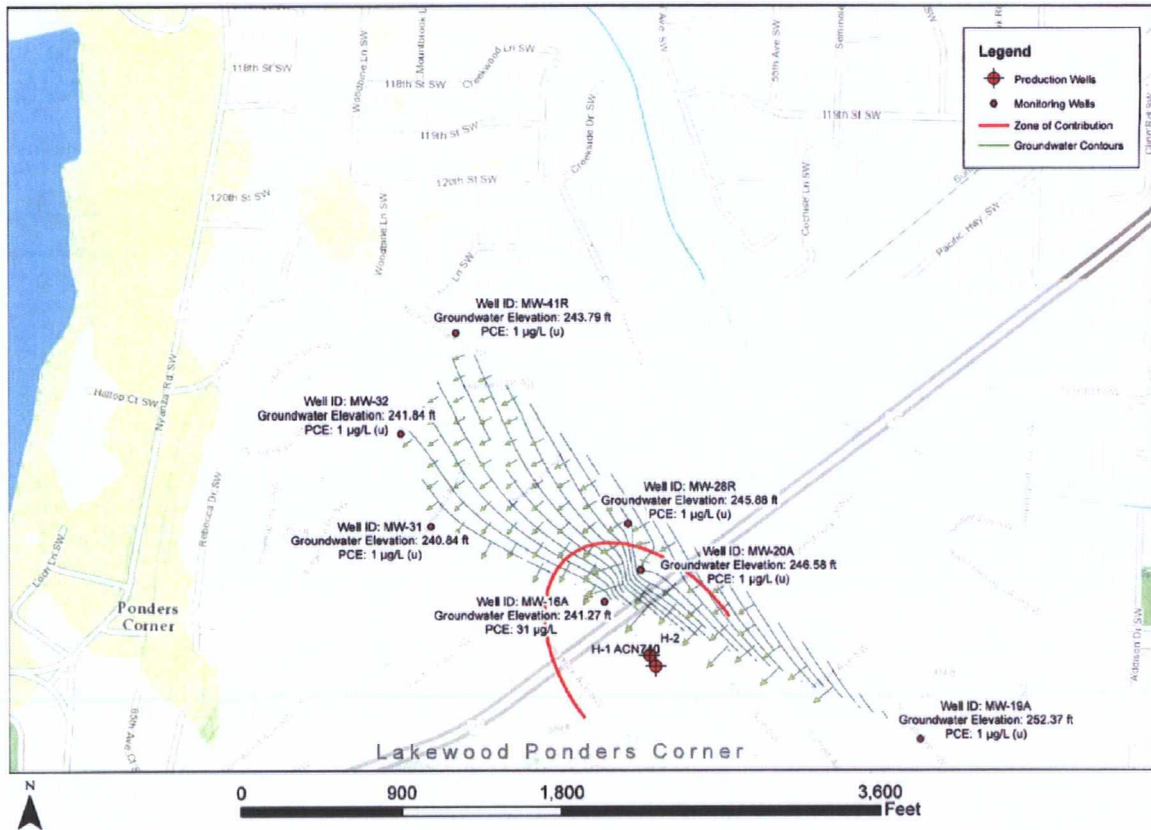


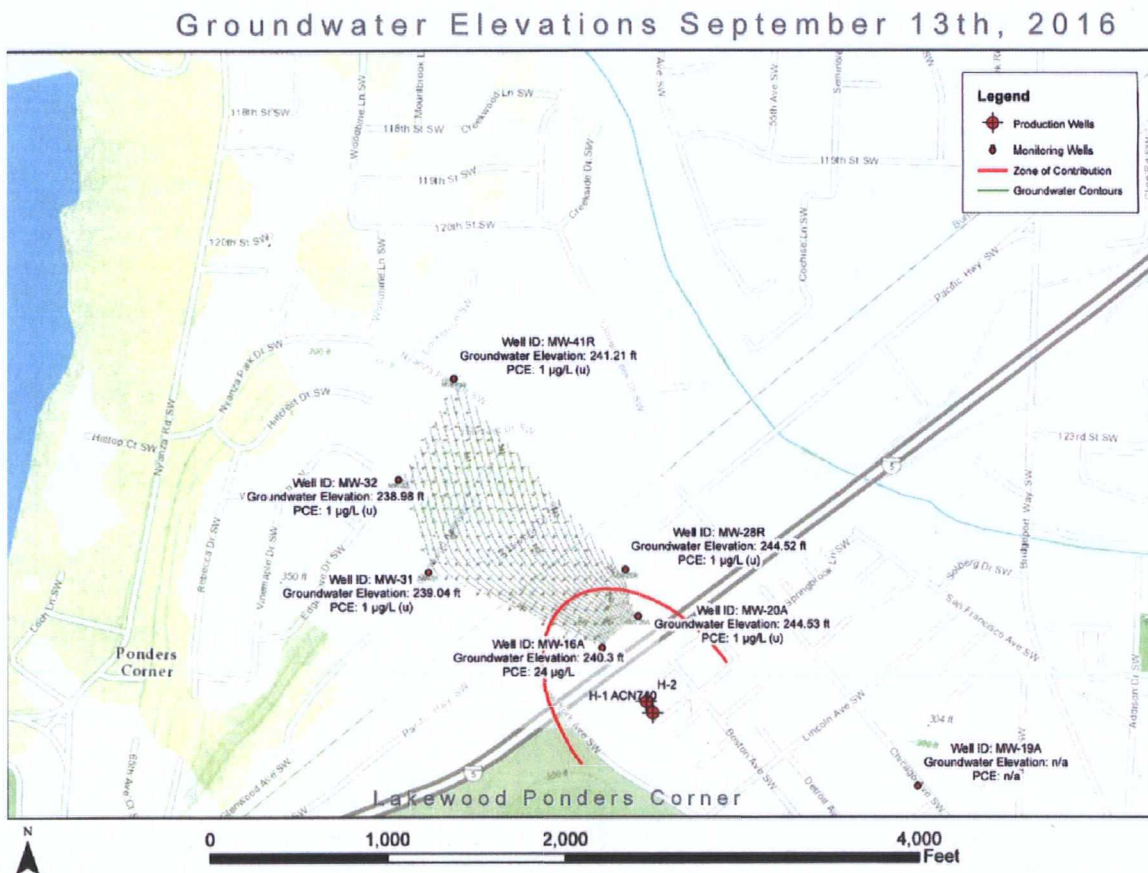
Figure 12.0

Figure 14.0 Groundwater Quality Sampling Collection Dates on the MW-31 Hydrograph (Groundwater elevation vs time)

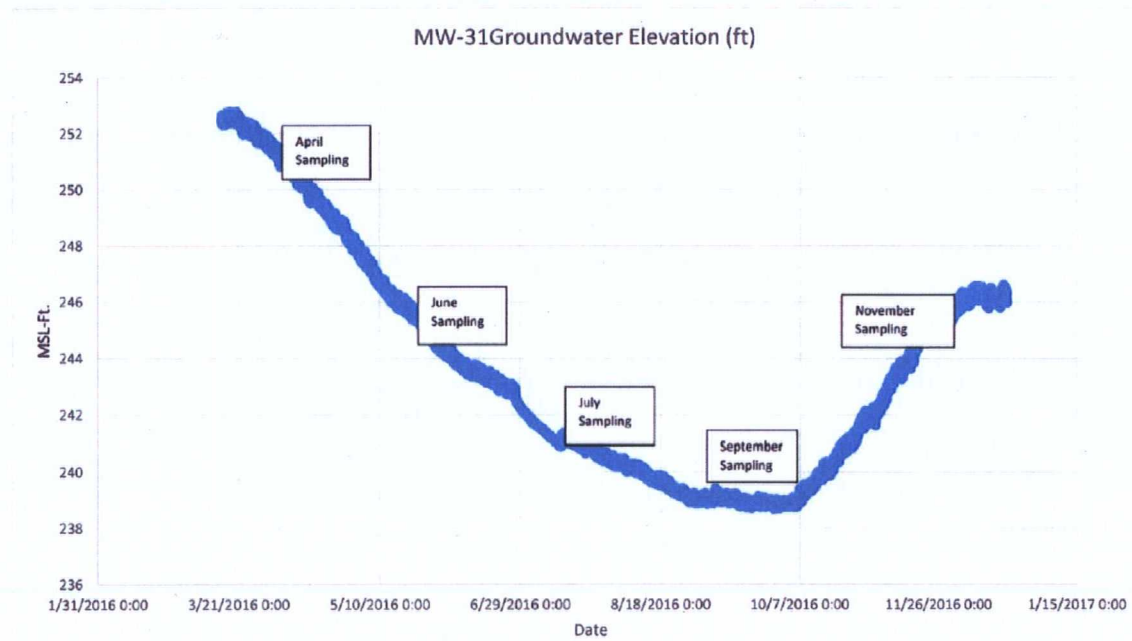


Figure 15.0

Tetrachlorethene (PCE) Groundwater Concentrations - $\mu\text{g/L}$ April 27th, 2016

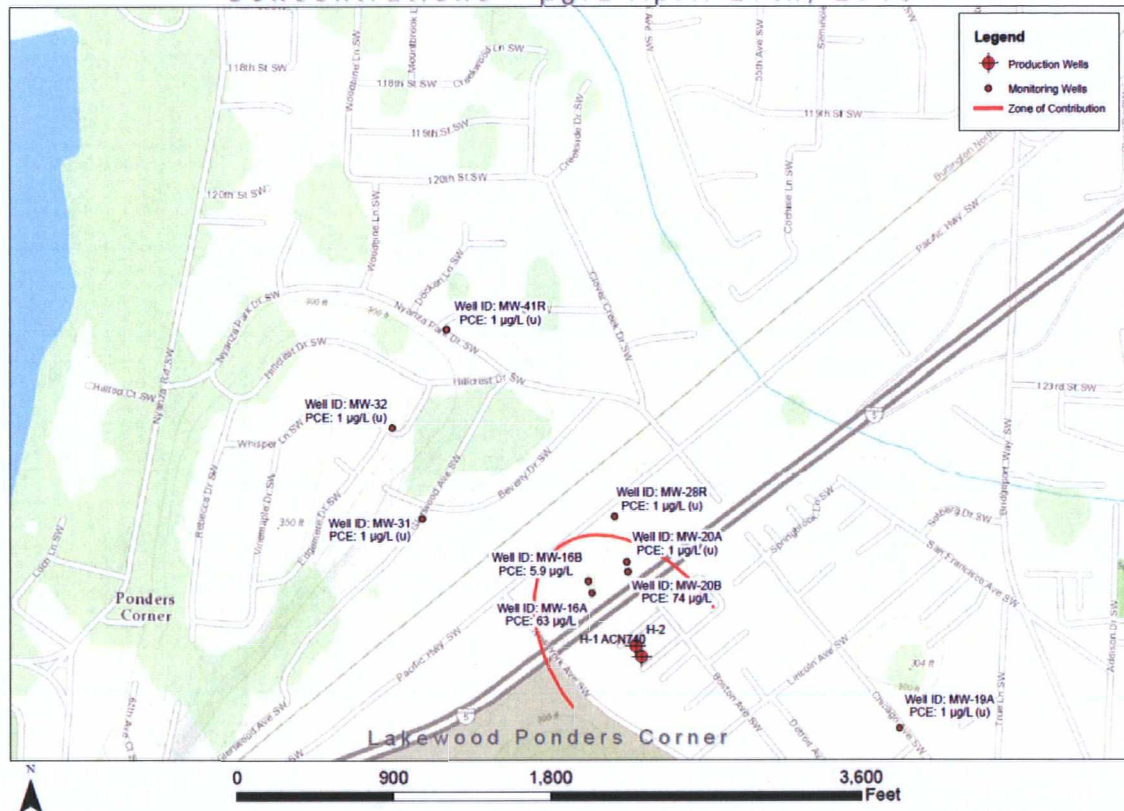


Figure 16.0

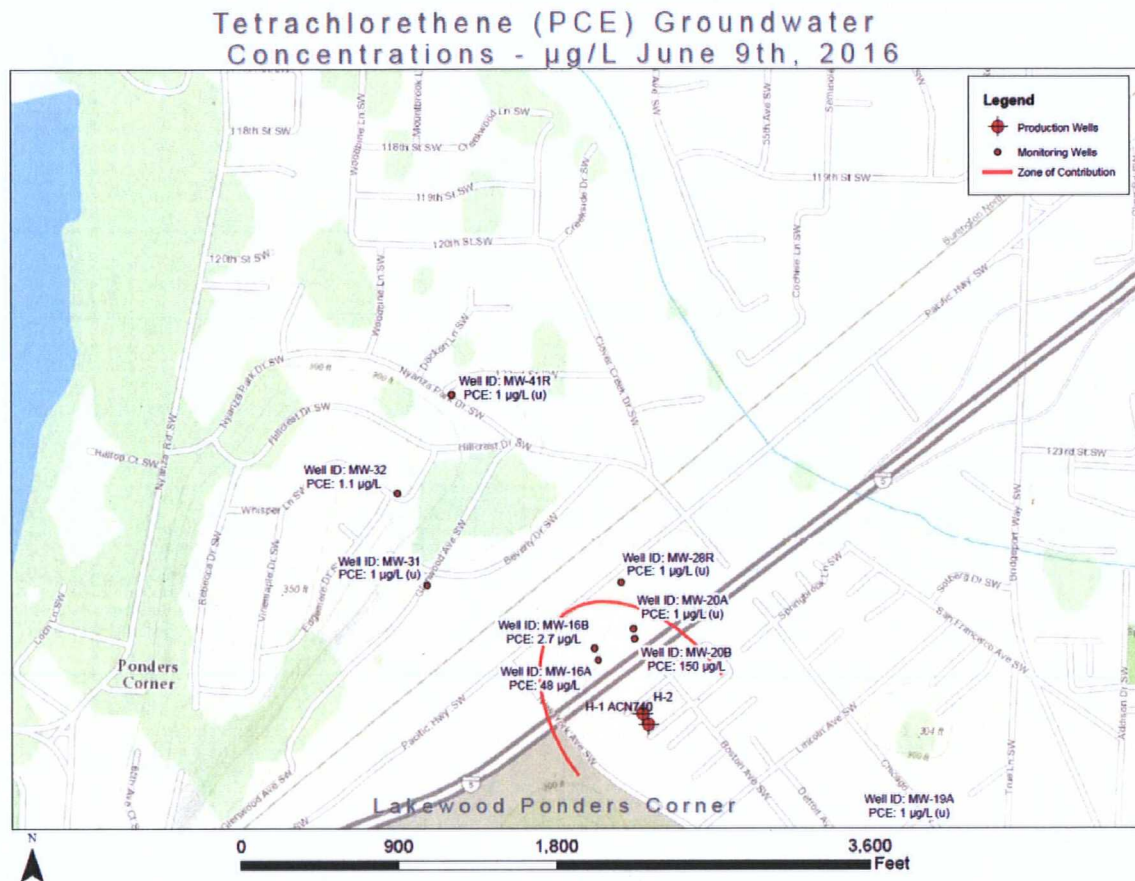


Figure 17.0

**Tetrachlorethene (PCE) Groundwater
Concentrations - $\mu\text{g/L}$ July 20th, 2016**

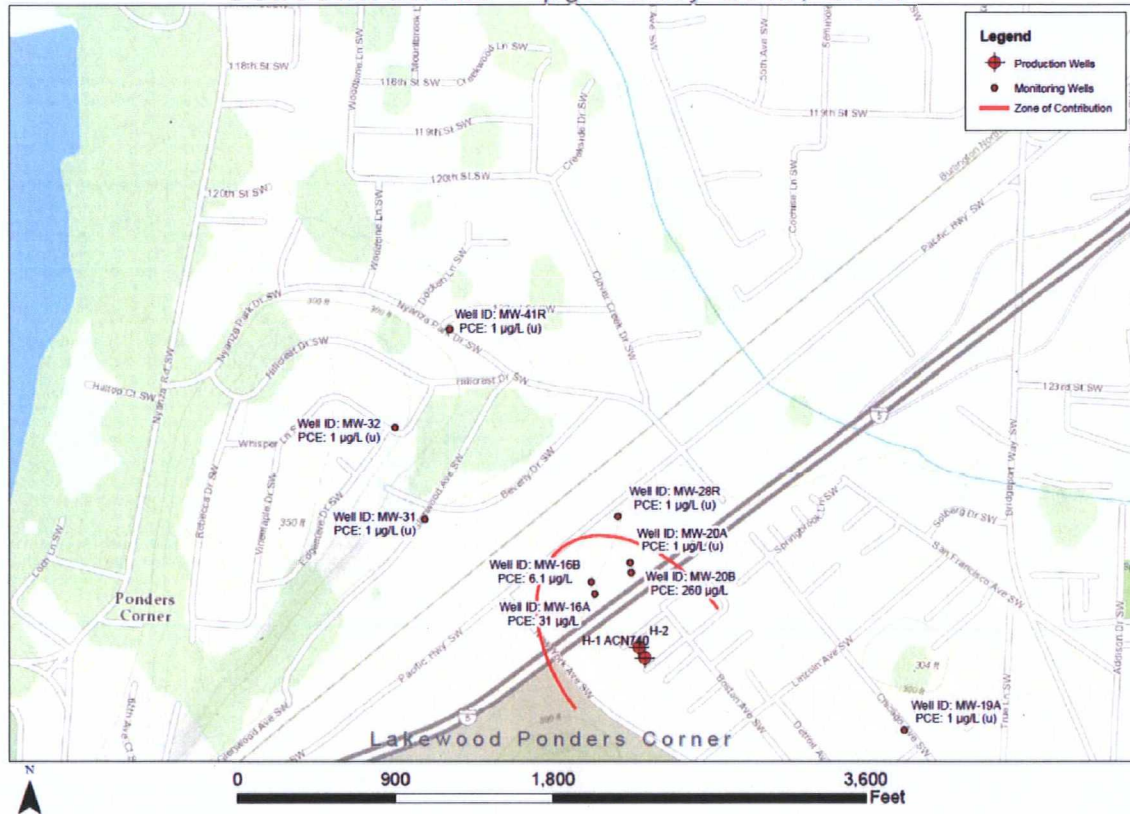


Figure 18.0

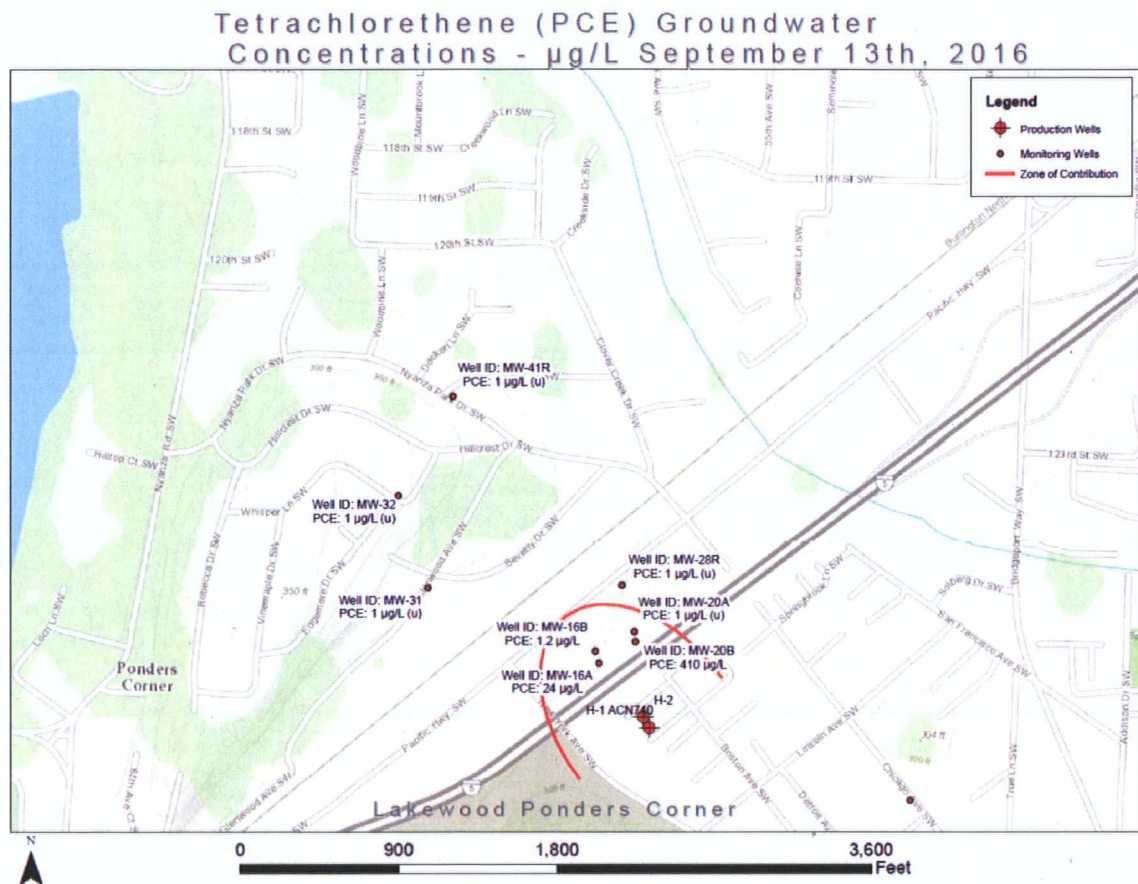


Figure 19.0

Tetrachlorethene (PCE) Groundwater
Concentrations - $\mu\text{g/L}$ November 17th, 2016

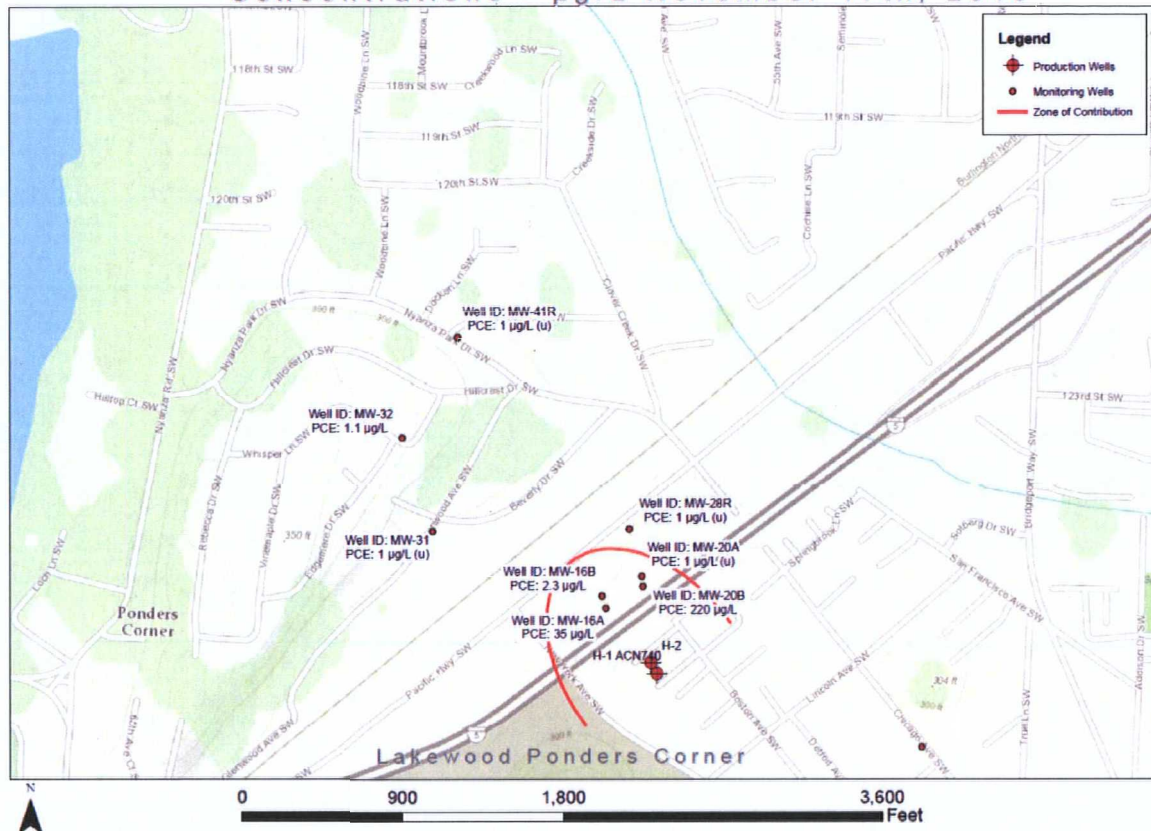
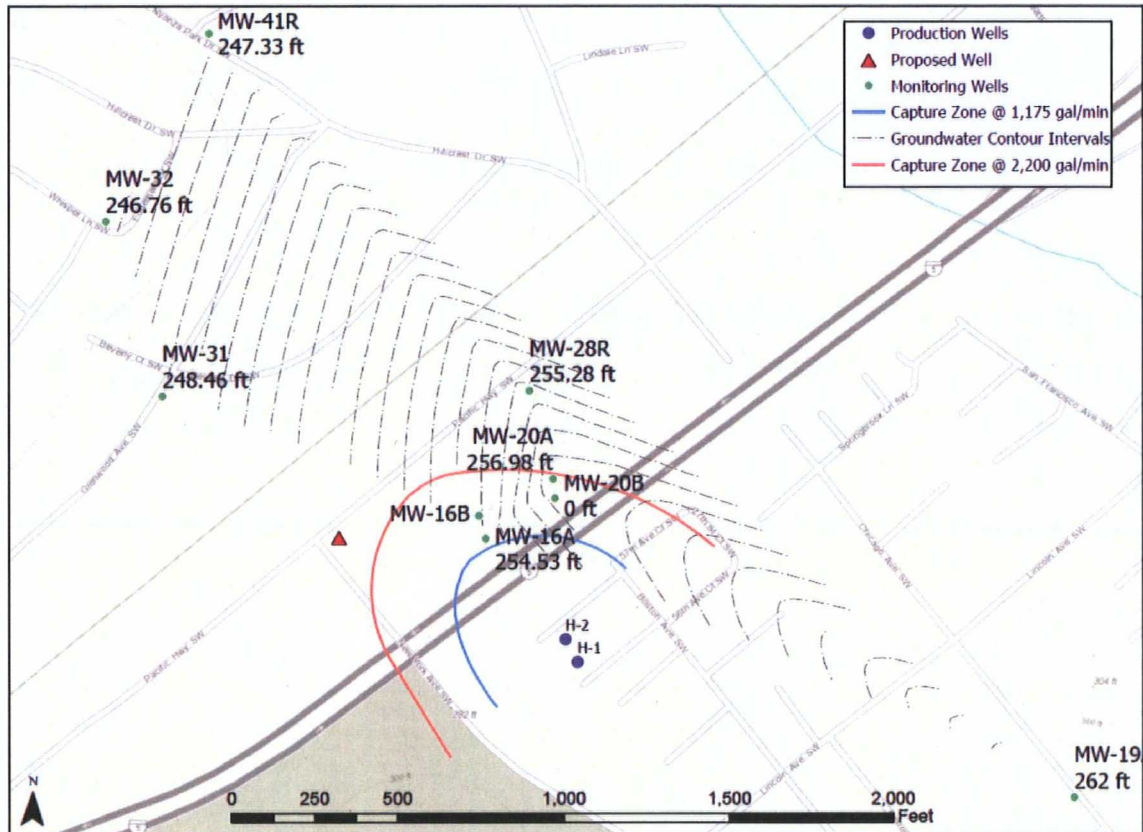


Figure 20.0 Location for the installation of a new monitoring well

April 27th 2016 Groundwater Elevation for Lakewood/Ponders Corner Superfund Site



TABLES

Table 1.0: Ponders Corner Select Monitoring Wells for Water Quality Sampling

Table 2.0: Water Quality Results for April 2016 Groundwater Sampling Event

Table 3.0 Water Quality Results for June 2016 Groundwater Sampling Event

Table 4.0 Water Quality Results for July 2016 Groundwater Sampling Event

Table 5.0 Water Quality Results for September 2016 Groundwater Sampling Event

Table 6.0 Water Quality for November 2016 Groundwater Sampling Event

Table 1.0: Ponders Corner Select Monitoring Wells for Water Quality Sampling

Well Number	State Plane Coordinates		Top of PVC casing Elevation (in feet)	Screen interval (BGS)	Field Measurements ^a	Laboratory Analysis
MW-16 A	Northing 666131.64	Easting 1139260.28	284.06	105 to 110 (AO)	Water level (manual and electronic), pH, DO, Conductivity, Temperature, ORP, Turbidity	Target VOCs
MW-19 A	665352.06	1141046.19	291.24	96 to 106 (AO)	Water level (manual), pH, DO, Conductivity, Temperature, ORP, Turbidity	Target VOCs
MW-19 B	665352.06	1141046.19	290.51	59 to 63 (VT)	Water level (manual), pH, DO, Conductivity, Temperature, ORP, Turbidity	Target VOCs
MW-20 A	666311.06	1139461.97	281.26	93 to 103 (AO)	Water level (manual and electronic), pH, DO, Conductivity, Temperature, ORP, Turbidity	Target VOCs
MW-20 B	666311.06	1139461.97	281.03	43 to 53 (VT)	Water level (manual and electronic), pH, DO, Conductivity, Temperature, ORP, Turbidity	Target VOCs
MW- 28R(A)	666576.55	113939.62	280.17	88 to 98 (AO)	Water level (manual and electronic), pH, DO, Conductivity, Temperature, ORP, Turbidity	Target VOCs
MW-31	666560.30	1138286.78	280.11	78 to 93 (AO)	Water level (manual and electronic), pH, DO, Conductivity, Temperature, ORP, Turbidity	Target VOCs
MW-32	667086.92	1138118.58	302.74	102-117 (AO)	Water level (manual and electronic), pH, DO, Conductivity, Temperature, ORP, Turbidity	Target VOCs
MW-41R (A)	667652.45	1138428.81	273.74	85-95 (AO)	Water level (manual), pH, DO, Conductivity, Temperature, ORP, Turbidity	Target VOCs
MW-16B	666131.64	1139260.28	283.80	75-77 (AO)	Water level (manual), pH, DO, Conductivity, Temperature, ORP, Turbidity	Target VOCs

AO- Advance Outwash sands

VT-Vashon Till

^a Where electronic water level is indicated; a transducer will be installed in the well for the project.

Table 2.0 Water Quality Results for April 2016 Groundwater Sampling Event

Date	Monitoring Well No.	Tetrachlorethene (µg/L)	Trichlorethene (µg/L)	Cis-1,2-Dichlorethene (µg/L)	Vinyl chloride (µg/L)
4/27/2016	MW-28R(A)	1.0 U	1.0 U	1.0 U	1.0 U
4/28/2016	MW-16A	63	1.1	1.4	1.0 U
4/28/2016	MW-16B	5.9	1.0 U	1.0 U	1.0 U
4/27/2016	MW-19A	1.0 U	1.0 U	1.0 U	1.0 U
4/27/2016	MW-19B	1.0 U	1.0 U	1.0 U	1.0 U
4/27/2016	MW-20A	1.0 U	1.0 U	1.0 U	1.0 U
4/27/2016	MW-20B	74	1.5	2.1	1.0 U
4/28/2016	MW-31	1.0 U	1.0 U	1.0 U	1.0 U
4/28/2016	MW-32	1.0 U	1.0 U	1.0 U	1.0 U
4/28/2016	MW-41R (A)	1.0 U	1.0 U	1.0 U	1.0 U
4/28/2016	MW-16A (duplicate)	57	1.1	1.3	1.0 U

Bold detections above the MCLs

U- The analyte was not detected at or above the reported value.

Table 3.0 Water Quality Results for June 2016 Groundwater Sampling Event

Date	Monitoring Well No.	Tetrachlorethene (µg/L)	Trichlorethene (µg/L)	Cis-1,2-Dichlorethene (µg/L)	Vinyl Chloride (µg/L)
6/8/2016	MW-28R(A)	1.0 U	1.0 U	1.0 U	1.0 U
6/8/2016	MW-16A	48	1.0 U	1.1	1.0 U
6/8/2016	MW-16B	2.7	1.0 U	1.0 U	1.0 U
6/9/2016	MW-19A	1.0 U	1.0 U	1.0 U	1.0 U
6/9/2016	MW-19B	1.0 U	1.0 U	1.0 U	1.0 U
6/8/2016	MW-20A	1.0 U	1.0 U	1.0 U	1.0 U
6/8/2016	MW-20B	150	3.5	5.5	1.0 U
6/9/2016	MW-31	1.0 U	1.0 U	1.0 U	1.0 U
6/9/2016	MW-32	1.1	1.0 U	1.0 U	1.0 U
6/9/2016	MW-41R(A)	1.0 U	1.0 U	1.0 U	1.0 U
6/9/2016	MW-19A (duplicate)	1.0 U	1.0 U	1.0 U	1.0 U

Bold detections above the MCLs

U- The analyte was not detected at or above the reported value.

Table 4.0 Water Quality Results for July 2016 Groundwater Sampling Event

Date	Monitoring Well No.	Tetrachlorethene (µg/L)	Trichlorethene (µg/L)	Cis-1,2-Dichlorethene (µg/L)	Vinyl Chloride (µg/L)
7/21/2016	MW-28R(A)	1.0 U	1.0 U	1.0 U	1.0 U
7/21/2016	MW-16A	31	1.0 U	1.0 U	1.0 U
7/21/2016	MW-16B	6.1	1.0 U	1.0 U	1.0 U
7/20/2016	MW-19A	1.0 U	1.0 U	1.0 U	1.0 U
7/20/2016	MW-19B	1.0 U	1.0 U	1.0 U	1.0 U
7/21/2016	MW-20A	1.0 U	1.0 U	1.0 U	1.0 U
7/21/2016	MW-20B	260	5.9	11	1.0 U
7/21/2016	MW-31	1.0 U	1.0 U	1.0 U	1.0 U
7/20/2016	MW-32	1.0 U	1.0 U	1.0 U	1.0 U
7/20/2016	MW-41R(A)	1.0 U	1.0 U	1.0 U	1.0 U
7/21/2016	MW-16A (duplicate)	34	1.0 U	1.0 U	1.0 U

Bold detections above the MCLs

U- The analyte was not detected at or above the reported value.

Table 5.0 Water Quality Results for September 2016 Groundwater Sampling Event

Date	Monitoring Well No.	Tetrachlorethene (µg/L)	Trichlorethene (µg/L)	Cis-1,2-Dichlorethene (µg/L)	Vinyl Chloride (µg/L)
9/13/2016	MW-28R(A)	1.0 U	1.0 U	1.0 U	1.0 U
9/13/2016	MW-16A	24	1.0 U	1.0 U	1.0 U
9/13/2016	MW-16B	1.2	1.0 U	1.0 U	1.0 U
9/13/2016	MW-20A	1.0 U	1.0 U	1.0 U	1.0 U
9/13/2016	MW-20B	410	7.3	12	1.0 U
9/14/2016	MW-31	1.0 U	1.0 U	1.0 U	1.0 U
9/14/2016	MW-32	1.0 U	1.0 U	1.0 U	1.0 U
9/14/2016	MW-41R(A)	1.0 U	1.0 U	1.0 U	1.0 U
9/13/2016	MW-20B	430	7.3	13	1.0 U

Bold detections above the MCLs

U- The analyte was not detected at or above the reported value.

Table 6.0 Water Quality for November 2016 Groundwater Sampling Event

Date	Monitoring Well No.	Tetrachlorethene (µg/L)	Trichlorethene (µg/L)	Cis-1,2-Dichlorethene (µg/L)	Vinyl Chloride (µg/L)
11/17/2016	MW-28R(A)	1.0 U	1.0 U	1.0 U	1.0 U
11/17/2016	MW-16A	35	1.0 U	1.0 U	1.0 U
11/17/2016	MW-16B	2.3	1.0 U	1.0 U	1.0 U
11/17/2016	MW-20A	1.0 U	1.0 U	1.0 U	1.0 U
11/17/2016	MW-20B	220	6.7	14	1.0 U
11/18/2016	MW-31	1.0 U	1.0 U	1.0 U	1.0 U
11/18/2016	MW-32	1.1	1.0 U	1.0 U	1.0 U
11/18/2016	MW-41R(A)	1.0 U	1.0 U	1.0 U	1.0 U
11/17/2016	MW-20B (duplicate)	250	6.8	14	1.0 U

Bold detections above the MCLs

U- The analyte was not detected at or above the reported value.

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Appendices

Appendix A. - Capture Zone Width Calculation

Appendix B. - Quality Assurance Project Plan (QAPP)

Appendix C. - Ponders Corner VOA Data

April 2016-SFP-105A

June 2016-SFP-105B

July 2016-SFP-105C

September 2016-SFP-105D

November 2016-SFP-105E

Appendix D. Groundwater Sampling log

April 2016

June 2016

July 2016

September 2016

November 2016

Appendix E. Electronic Transducer data

March 2016

June 2016

July 2016

September 2016

November 2016

December 2016

Appendix A – Capture Zone Width Calculation

This calculation is an analytical solution to determine the geometry of a pumping well or the point of stagnation or the distance from the well to the downgradient end of the capture zone along the central line of the flow direction (X_0). This solution also calculates the maximum capture zone width from the central line or the pumping well (Y_{max} & Y_{well}). This analytical solution is taken from EPA 600/R-08/003/ January 2008/ www.epa.gov/ord. *A Systematic Approach for Evaluation of Capture Zones at Pump and Treat Systems.*

The following are assumptions that are made in order to use this calculation.

- Homogeneous, isotropic, confined aquifer of infinite extent
- Uniform aquifer thickness
- Fully penetrating extraction well(s)
- Uniform regional horizontal hydraulic gradient
- Steady-state flow
- Negligible vertical gradient
- No net recharge, or net recharge is accounted for in regional gradient
- No other sources of water introduced to aquifer due to extraction (e.g. from rivers, or leakage from above or below)

$$X_0 = -Q / 2\pi Ti ; Y_{max} = +/- Q / 2Ti ; Y_{well} = +/- Q / 4Ti$$

Where:

Q = extraction rate

T = transmissivity, $K \cdot b$

K = hydraulic conductivity

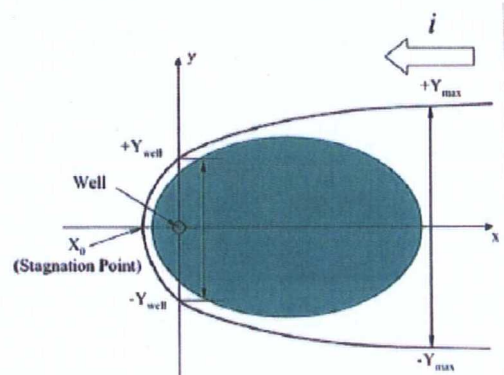
B = saturated thickness

I = regional hydraulic gradient

X_0 = the distance from the well to the downgradient end of the capture zone along the central line of the flow direction.

Y_{max} = maximum capture zone width from the central line of the plume

Y_{well} = capture zone width at the location of well from central line of the plume



The following are the calculations for the stagnation point and capture width for both the combine discharge rate of H1 and H2 at a discharge rate of 2,200 GPM and just H1 at a discharge rate of 1,175 GPM.

$$X_0 = Q / 2\pi Ti;$$

Q= combine maximum flow rate for both H1 & H2 or 2, 200 gals/min or

$$423504 \text{ ft}^3/\text{day}$$

$$T = 26,800 \text{ ft}^2/\text{day}$$

$$2\pi = 6.28$$

$$i = 0.0035 \text{ ft./ft.}$$

$$\begin{aligned} X_0 &= \frac{423504 \text{ ft}^3/\text{day}}{6.28 * 26,800 \text{ ft}^2/\text{day} * 0.0035} \\ &= \frac{423504 \text{ ft}^3/\text{day}}{589 \text{ ft}^2/\text{day}} \\ &= \underline{719 \text{ feet}} \end{aligned}$$

$$Y_{\text{well}} = \pm Q / 4Ti$$

$$\begin{aligned} &= \frac{423504 \text{ ft}^3/\text{day}}{4(26,800 \text{ ft}^2/\text{day}) * 0.0035} \\ &= \frac{423504 \text{ ft}^3/\text{day}}{375.2 \text{ ft}^2/\text{day}} \\ &= \underline{1,128.7 \text{ feet}} \end{aligned}$$

1- The range of Transmissivity for this aquifer was 4.1×10^4 to 4.1×10^5 gallons/ day/ foot or 54,809 to 5,480 ft^2/day (Keely & Wolf, 1983). I used a value of 26,800 ft^2/day or a mid-point range for the transmissivity and based on the aquifer thickness of 65-feet the estimate for the hydraulic conductivity would be 412 ft./day.

A second calculation was performed for the Capture Zone or Zone of contribution with 60% pumping from H1 and H2 or 1,320 gals/min but instead of 60% of pumping this calculation will show the pumping of just one production well or H1 at a $Q = 1,175$ gallons per minute

$$Q = 1,175 \text{ gals/min or } 226,187 \text{ ft}^3/\text{day}$$

$$X_0 = \frac{226,187 \text{ ft}^3/\text{day}}{589 \text{ ft}^2/\text{day}}$$

= 384 feet or the point of stagnation would be 384 feet from H1.

$$Y_{\text{well}} = \pm Q / 4T_i$$

$$= \frac{226,187 \text{ ft}^3/\text{day}}{4(26,800 \text{ ft}^2/\text{day}) * 0.0035}$$

= 602.84 feet is the width of capture.